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THESIS

A COST ESTIMATION MODEL FOR COMMANDER NAVAL AIR FORCES PACIFIC'S TACAIR F/A-18S AVIATION DEPOT LEVEL REPAIR COSTS

by

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A COST ESTIMATION MODEL FOR COMMANDER NAVAL AIR FORCES PACIFIC'S TACAIR F/A-18S AVIATION DEPOT LEVEL REPAIR COSTS

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LIST OF ACRONYMS

ACES	Aviation Cost Evaluation System
AVDLR	Aviation Depot Level Repairable
CNA	Center for Naval Analyses
CNAP	Commander Naval Air Forces Pacific
CPH	Costs Per Hour
DoD	Department of Defense
DoN	Department of the Navy
FAS	Fleet Air Support Squadrons
FHP	Flight Hour Program
FRS	Fleet Replacement Squadrons
FY	Fiscal Year
HPT	High Pressure Turbine
LPT	Low Pressure Turbine
MAD	Mean Absolute Deviation
MARFORLANT	Marine Forces Atlantic
OPTEMPO	Operational Tempo
PMR	Primary Mission Readiness
TACAIR	Tactical Aircraft
T/M/S	Type/Model/Series

I. INTRODUCTION

A. PURPOSE

Aviation depot level repair costs have skyrocketed for the Commander Naval Air Forces Pacific (CNAP) Tactical Aircraft (TACAIR) F/A-18s over the past ten years. These repair costs result from maintenance repairs performed at aviation industrial establishments to ensure the flying integrity of airframes and flight systems. Maintenance is performed on material requiring major overhauls or rebuilding of part assemblies, subassemblies, and end items, which do not require frequent repair [Ref. 1:p. 145]. Several factors have contributed to the rise in depot level repair costs such as the high utilization rate and the increasing age of the Department of the Navy's (DoN's) F/A-18s. This research will address those issues with the goal of validating the extent to which, if any; they contribute to the rising costs.

Naval aviation is capable of operating anywhere in the world. This high degree of flexibility has resulted in an over-utilization rate of many of the Navy's aircraft including the F/A-18. More than 300 F/A-18s will require earlier than planned or budgeted service life extensions because of this high-utilization rate [Ref. 2].

This high utilization rate has also created problems for CNAP in estimating future flight hour costs. If aircraft are flown more than what was expected or planned, this results in higher maintenance, fuel and consumable costs not planned for in their Flight Hour Program (FHP) budget. As a result, funding shortfalls develop and CNAP is required to find money to pay for these unexpected costs. The rise in maintenance costs is one reason for these funding shortfalls, and more specifically, for Aviation Depot Level Repairable (AVDLR) costs. Navy F/A-18C's AVDLR costs have risen by more than 72% in the last five years. This dramatic increase has put an added burden on CNAP's FHP since that program has only seen a 15% increase in funding for the same period. The unfortunate result of paying for the high F/A-18 AVDLR costs has lead to either fewer hours flown or money taken out of other aircrafts' flying hour budgets.

The increase in the age of the aircraft is a second cause cited for the increase in AVDLR costs for CNAP's TACAIR F/A-18s. The increase in the age is largely caused by DoN's inability to replace them with new aircraft. Post Desert-Storm/Desert Shield saw a decrease in military spending for the Department of Defense (DoD) and the DoN, and only recently has that trend been reversed. Refer to Figures 1-1 and 1-2.

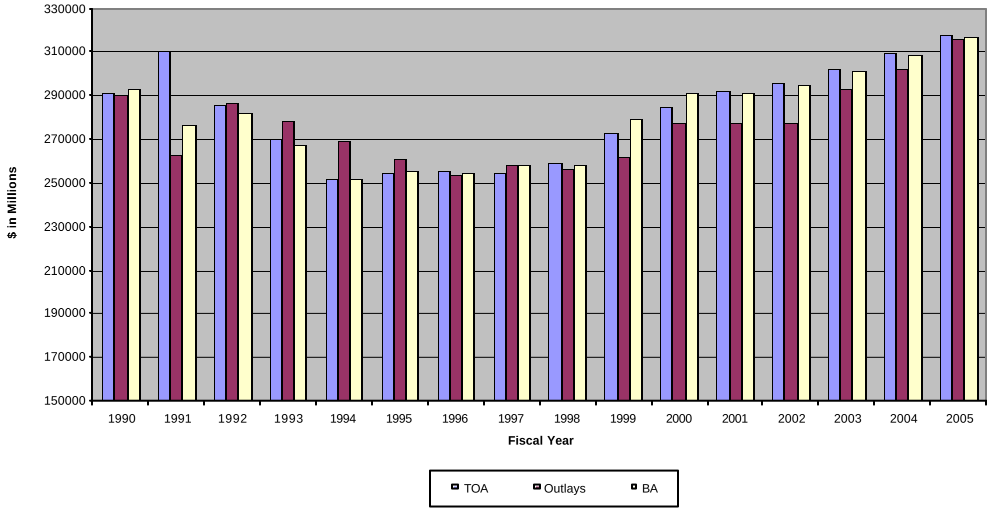

Figure 1-1. DoD Budget Estimates [Ref. 3: pp. 62-145].

Years of declining budgets in the 1990's, coupled with increased replacement costs, have resulted in DoN's inability to recapitalize its aging fleet of F/A-18s.

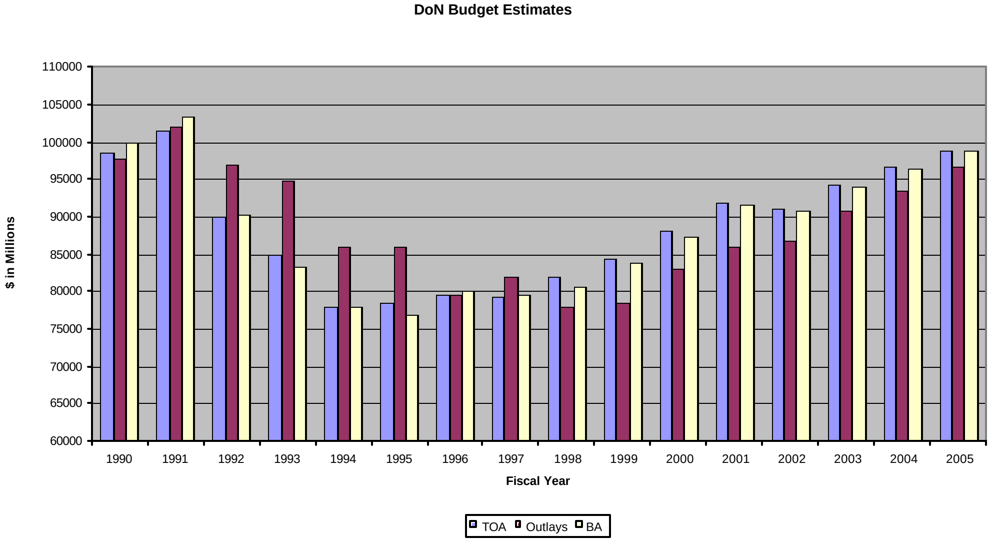

Figure 1-2. DoN Budget Estimates [Ref. 3:pp. 62-145].

In 1990, DoN was able to purchase a F/A-18 at a per-unit cost of $36.11 million. Eight years later, the Navy had to pay $47.12 million per unit [Ref. 4: p. BA-1, 37], which is more than a 30% increase in eight years while the DoN's budget has only seen modest plus-ups in the past few years. This dramatic increase in aviation recapitalization costs has caused, for the first time in DoN's history, the average age of its aircraft to exceed the average age of its combatant ships [Ref. 2]. This has resulted in higher flight costs and a dramatic increase in maintenance costs because the DoN must fly older aircraft. These higher maintenance costs significantly contributed to the rise in AVDLR expenses and helped create funding shortfalls in the Flying Hour Program for the Commander Naval Air Forces Pacific.

B. OBJECTIVES AND RESEARCH QUESTIONS

The primary objective of this research was to evaluate and develop a model that can predict CNAP's TACAIR F/A-18 AVDLR costs to within 1% of the actual amount. Achieving this goal required an answer to the following research questions:

- Is there any evidence to show that CNAP has spent more money on AVDLR costs to maintain its older model F/A-18s?
- How close are budgeted costs to actual costs and does a discrepancy exist to cause this?
- Are there any components that have had a shorter life cycle than what was expected, and if so, did they contribute to the rising costs at CNAP?

C. SCOPE

This research is concentrated on CNAP's TACAIR F/A-18s AVDLR costs. This required input data on Navy A and C models and Marine Corps C and D models. F/A-18s assigned to Fleet Replacement Squadrons (FRS) and Fleet Air Support Squadrons (FAS) are not included in this research.

D. METHODOLOGY

Historical data from CNAP's ACES (Aviation Cost Evaluation System) database was the primary source used in developing this model. Personal interviews with CNAP's FHP managers, the F/A-18 Class Desk, Aviation Depot Production Manager, and the different Wing and Station Aircraft maintenance officers were also used to obtain real-time information that helped to construct this model.

E. THESIS ORGANIZATION

This thesis is divided into five chapters.

Chapter I is the introduction chapter and states the importance of the research. It describes the research objectives and lists research questions, the scope of the research, and the methodology used to conduct the research. The chapter also contains an overview of the thesis structure.

Chapter II provides the methodology used to create a forecasting model.

Chapter III presents the data obtained from CNAP's archives on F/A-18 AVDLR costs. The chapter also breaks down the data to see if any trends exist and that information is used to create an AVDLR cost model.

Chapter IV is the analysis chapter. In this chapter the results presented in Chapter III are examined to explain any deviations in the actual outcome to the forecasted results. This chapter also lists several causes for the increase in CNAP's AVDLR costs.

Chapter V summarizes the research findings and answers the primary and secondary research questions and offers suggestions for further research.

II. THEORETICAL-BACKGROUND

A. INTRODUCTION

This chapter focuses on the methodology used in developing a model to estimate Commander Naval Air Forces Pacific's (CNAP) F/A-18 Aviation Depot Level Repair (AVDLR) costs. This research used a quantitative analysis approach that incorporates time series and regression analysis techniques to manipulate the data into meaningful information.

B. QUANTITATIVE ANALYSIS APPROACH

The quantitative analysis approach is broken down into the seven steps listed in Figure 2-1 [Ref. 5:p. 2].

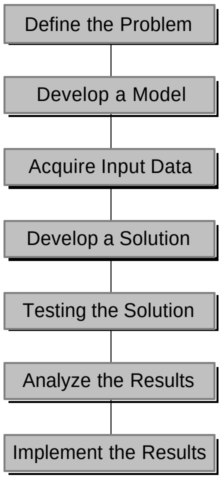

Figure 2-1. Quantitative Analysis Approach. [From: Ref. 5:p. 6]

The first and most important step in this approach is to develop a clear and concise problem statement. The problem statement for this research was stated earlier in Chapter I.

The second step is to develop a model which is the focus of this chapter. A problem with analyzing cost data from the Flight Hour Program (FHP) is that there is a tendency for the data to be autocorrelated when it is collected monthly or annually. This problem is discussed in more detail later in the chapter. Solving for this occurrence requires the use of some mathematical techniques that account for the effects of time in the analysis. In this thesis, a time-series analysis using the classical decomposition method as well as lagged regression techniques are utilized to help eliminate the autocorrelation problem.

The classical decomposition model is broken down into four components: trend, seasonality, cycles, and random variation.

- ***Trend*** (T) represents the long-term behavior of the data over time; it can increase, decrease or stay constant.
- ***Seasonality*** (S) is said to exist if the value of the variable changes according to a seasonal regularity. A good example is department stores sales for the holiday season. This pattern of demand can fluctuate above or below the trend line that occurs every year.
- ***Cycles*** (C) are patterns in the data that occur every several years. These fluctuations may depend on the state of the economy, a company's business cycle or even a presidential election.
- ***Random Variation*** (R) are "blips" in the data caused by chance and unusual situations. [Ref. 6]

There are several alternative approaches to the classical decomposition method: multiplicative and additive formulas. The multiplicative method was used for this thesis. There is no distinct advantage of using either formula but the multiplicative method is the more commonly used of the two. Both formulas are shown in Equation 2-1.

$$\mathbf{Y=T*S*C*R \quad or \quad Y=T+S+C+R}$$

Equation 2-1. Multiplicative and Additive Formulas.

The first step in decomposing time series data is to factor out the existence of any trend and several methods are used. The most common is to use a moving average to smooth the data. Moving averages (M) are useful when assuming that the output is steady over time. A ratio-to-moving-average is one method that isolates trend and cyclical factors of the data by calculating a moving average whose number of terms is equal to the length of seasonality [Ref. 6]. The moving average is expressed mathematically as

$$M = T*C$$

An exponential smoothing formula is another alternative approach to isolating the trend line. The exponential smoothing formula is mathematically written as

$$F_{(t)} = F_{(t-1)} + \alpha(A_{(t-1)} - F_{(t-1)})$$

where

$F_{(t)}$=new forecast
$F_{(t-1)}$=previous forecast
α=Smoothing constant $(0?\alpha?1)$
$A_{(t-1)}$= previous period’s actual demand

Selecting the appropriate α is the most important step in this formula. Using a mean absolute deviation (MAD) can aid in selecting the most appropriate α that gives the best results if several α’s are selected.

The second step in decomposing time series data is to isolate any seasonality. This is accomplished by dividing the outputs (Y) by the moving average and taking the average for each season. This gives you a seasonality adjusted index, S, for each season. Once the seasonality index is obtained, divide Y by your seasonality index to obtain the seasonality-adjusted data, Y/S.

The third step is to run a linear regression of the seasonality-adjusted data with its appropriate Y values.

Linear regression is a technique that quantifies relationships between two or more variables [Ref. 6]. A simple regression model consists of two variables: an independent variable and a dependent variable. The letter X usually denotes the independent variable, which is sometimes called the explanatory variable, and Y usually denotes the dependent variable. Since regression seeks a linear relationship between the independent and dependent variables, the results of a regression analysis are represented by a formula of a straight line:

$$Y=a + bX$$

where a is the y-axis intercept and b is the slope of the line.

Five assumptions need to be met for regression analysis to succeed:

- Linearity
- Normality of Error Distribution
- Constant Variance (Homoscedasticity)
- Zero Expected Value of Errors
- Independence of Error Terms

Linearity is the assumption that the dependent variables are linearly related to the independent variables [Ref. 6]. The best method for determining if this assumption is true is to graph the data on an X versus Y scatter diagram. If a non-linear relationship exists, the data can be transformed using logarithmic, exponential or reciprocal methods to develop a linear relationship.

Normality of error distribution assumes the error terms from a properly conducted regression analysis follow a normal distribution. If the error terms do not conform to this assumption, the data may be skewed or inaccurate. The best method for verifying if the error terms follow a normal distribution is to graph the residual terms.

Constant Variance or homoscedasticity means the error terms are assumed to have a finite variance that is constant for all given values of X.

Zero expected value of errors terms is assumed to have a mean of zero. If the normal distribution and constant error term assumptions are met, the average of the error terms will be zero [Ref. 6].

Independence of error terms assumes that the error terms are independent of one another. If this assumption is violated, an autocorrelation will exist. The best technique to identify the existence of autocorrelation is to graph the error terms over time by running a Durbin-Watson test. The test is a summary measure of the amount of serial correlation in the error terms. With uncorrelated errors, the Durbin-Watson statistic takes the values near 2. If the errors are perfectly and positively correlated, the D-W statistic will be 0 [Ref. 6]. If a pattern or trend exists in the error terms then the model is not as accurate as it could be.

If all assumptions are met, regression can give accurate results by finding the best-fitting line that passes close to all data points so that the distance of the individual data points from the line is minimized [Ref 6]. The least squares method is the method regression used to complete this task.

The coefficient of correlation, more commonly referred to as R^2, measures the goodness of fit for a regression model. This value measures the relationship between the dependent and independent variable. A high R^2 indicates a strong correlation between the variables and the regression model. A high R^2 also indicates that the regression model can explain a significant amount of the error terms.

The third step in our quantitative analysis approach is to acquire input data. There are a number of sources that were used to collect data. In this research, the majority of the data were collected from CNAP's Aviation Cost Evaluation System (ACES) database and also by reviewing their historical archives. Personal interviews were also conducted to obtain the latest information on F/A-18 AVDLR costs.

The fourth step is to develop a solution which involves manipulating the data to arrive at the best solution. In this research, the results obtained from the time-series and regression analysis will help in the development of a solution to estimate CNAP's AVDLR costs.

The fifth step is to test the solution. The results obtained from the analysis will be compared to those of the budgeted and actual values. If the results meet the objectives of the research the next step would be to implement the results into next year's budget projections. This is step seven in the analysis. If the model fails to accurately estimate future AVDLR costs then further analysis is needed to discover why the model failed and what needs to be done to correct the problem. Once done, the corrections will be incorporated back into the model to better estimate next year's costs. This analysis corresponds to step six in the model development process.

C. SUMMARY

This chapter describes how the quantitative analysis method was used to develop a cost estimation model for CNAP's TACAIR F/A-18 AVDLR costs. It also discusses the components of a time-series analysis and how each factor can be used to isolate any trends or patterns in the data. The five assumptions of regression are also mentioned and a brief discussion followed to explain why each assumption must be met for a regression analysis to work properly.

The following chapter will use the techniques discussed in this chapter to determine future AVDLR cost for CNAP's F/A-18s.

III. CNAP'S COST DATA

A. INTRODUCTION

The purpose of this chapter is two-fold. First, to provide input data, and second, to develop a solution to estimate future Aviation Depot Level Repair (AVDLR) costs. Completing these tasks corresponds to steps three and four on the quantitative analysis approach described in Chapter II.

B. INPUT DATA

A comprehensive list of Commander Naval Air Forces Pacific's (CNAP) flight hour costs for the past ten years is provided in Appendix A. Using the information provided in that appendix, a graph of CNAP's AVDLR Cost Per Hour (CPH) was constructed. The results can be seen in Figure 3-1. Figure 3-1 also shows that Navy C, and Marine Corps C and D models have very similar AVDLR CPH patterns. Conversely, Navy As have a more irregular AVDLR CPH pattern. This irregular cost pattern is caused by several different factors. One of the most significant factors is the age difference between the A models and the C and D models.

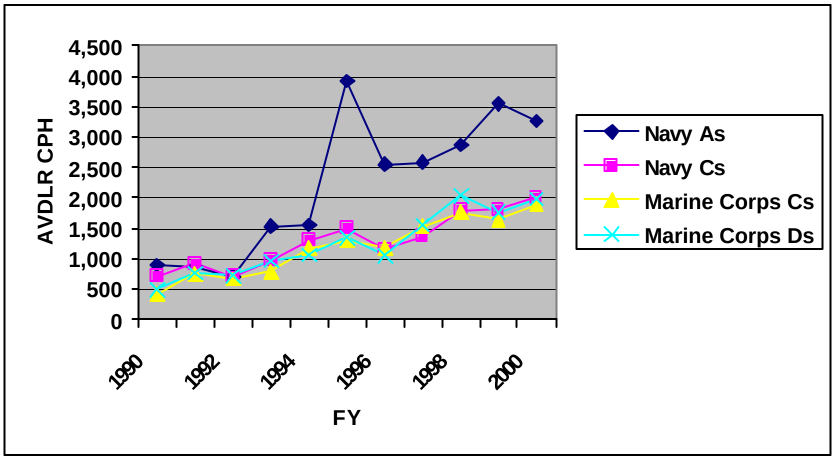

Figure 3-1. F/A-18 AVDLR Cost/Hour.

Commander Naval Air Forces Pacific's F/A-18A models average 14 years old while C models average 9.5 and D models average 8.5 years old. These figures represent an aggregate average of all CNAP's F/A-18 airframes. These figures include aircraft in FRSs, FASs, along with TACAIR units. Since aircraft are transferred between units on such a frequent basis, it is almost impossible to obtain an average age of only the TACAIR F/A-18s. As a result, this research will not be able to provide a quantitative analysis solely on the average age of CNAP's TACAIR F/A-18s and the rising costs of AVDLR costs.

What is similar for all models is the increase in AVDLR costs over time. Navy F/A-18A's AVDLR costs have risen by more than 360% in the past ten years while Navy F/A-18Cs, and Marine Corps F/A-18Cs and Ds AVDLR costs have risen by 280% for the same period. For all models, the most significant increase in AVDLR costs occurred between 1990-1995. AVDLR costs for all models doubled during this time frame.

C. DEVELOPING A SOLUTION

This research took a different approach than past theses in estimating future F/A-18 AVDLR costs. In Arkley's thesis, [Ref. 7], Arkley showed that F/A-18 AVDLR costs for reserve units are directly related to the amount of hours flown. Arkley's research involved running a regression analysis of AVDLR costs to the number of flight hours. The results of his research showed a very strong correlation between the two variables with R^2 values ranging from .679 to .960.

Gardiner [Ref. 11] took the same approach in his thesis as Arkley but used Marine Forces Atlantic's (MARFORLANT) aircraft rather than reserve units. In his research he found very little correlation between F/A-18 AVDLR costs and flight hours flown. In his research, he obtained R^2 values ranging from .011 to .433.

This research tried a different approach to evaluate F/A-18 AVDLR costs. This approach did not compare costs to hours flown but rather did a time analysis using the techniques described in Chapter II to see if this method would produce a more accurate way to estimate AVDLR costs.

This required solving three variables for each Type/Model/Series (T/M/S) F/A-18, AVDLR CPH, the number of aircraft per model per year, and the average number of hours flown per aircraft per year (AHFPY). Once all three variables are known for each T/M/S for each year, they can be entered into Equation 3-1 which gives the total AVDLR costs for that year and for that model aircraft.

Total AVDLR costs per model =(AVDLR CPH)*(Number of Aircraft)*(AHFPY)

Equation 3-1 Total AVDLR Costs per Model.

The first step in estimating future AVDLR costs is to determine AVDLR CPH for each T/M/S. Looking back at Figure 3-1 it can bee seen that patterns exist in the AVDLR cost data. Navy A models tend to have a three-year cost cycle while Navy C and Marine Corps C and D models have a four-year cost cycle indicating that costs increase for two or three years followed by a year of decreased costs. The classical decomposition method, described in Chapter II, was used to factor out this pattern along with any long-term trends.

To decompose the data first requires arranging the data into the appropriate seasonal cycles. Once the data are arranged, a time-series analysis can be completed. The results of this process are listed in Appendices B-F. Figures 3-2 through Figure 3-5 graph the results of the actual AVDLR costs compared to the results using the classical decomposition method for each model aircraft.

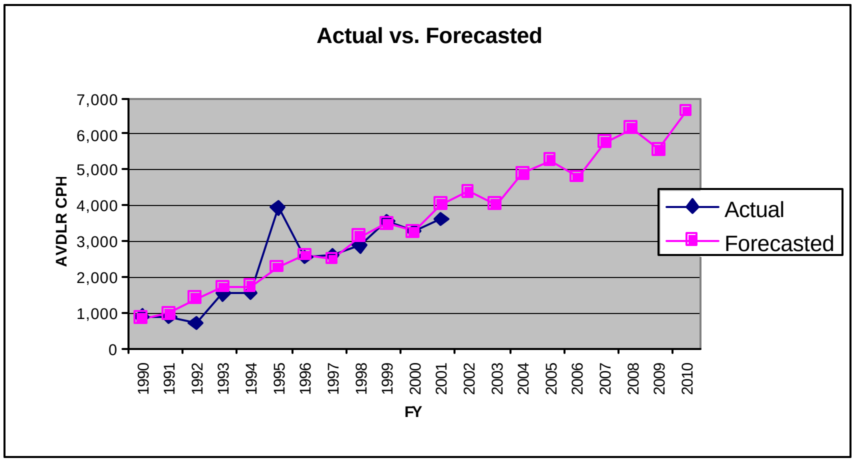

Figure 3-2. Navy F/A-18As AVDLR Actual vs. Forecasted CPH.

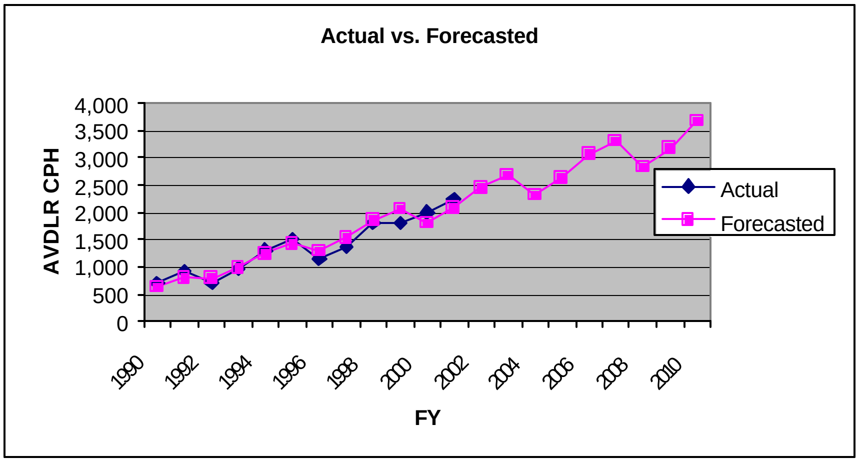

Figure 3-3. Navy F/A-18Cs AVDLR Actual vs. Forecasted CPH.

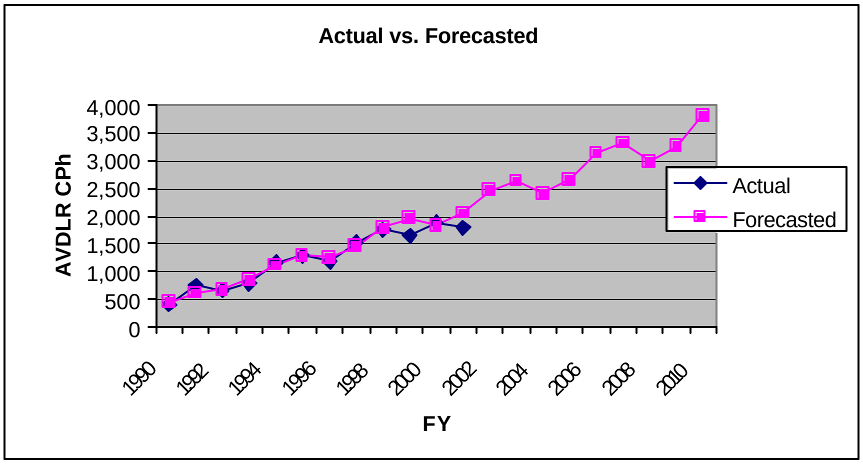

Figure 3-4. Marine Corps F/A-18Cs AVDLR Actual vs. Forecasted CPH.

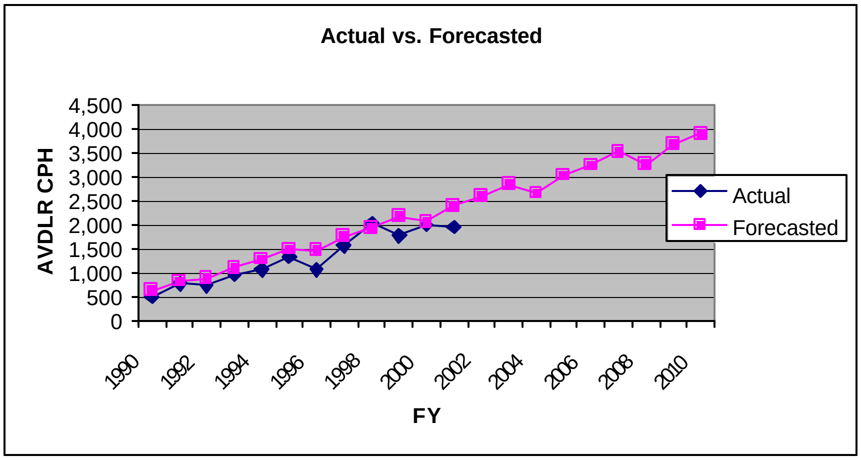

Figure 3-5. Marine Corps F/A-18Ds AVDLR Actual vs. Forecasted CPH.

The classical decomposition method was successful in forecasting past AVDLR CPH for Navy C and Marine Corps C and D models but was not as successful in forecasting Navy A model AVDLR costs. This is largely due to their irregular cost patterns.

The second step in estimating future AVDLR costs is to determine the number of aircraft for each T/M/S. Figure 3-6 shows the number of airframes per model for each fiscal year. Determining future values requires making an educated guess since a regression analysis cannot be run on the data because it violates the linearity assumption which is one of the five assumptions of linear regression. Based on past year's figures and from compiling information obtained from several interviews, in the short term of one to two years, the number of TACAIR A, C, and D models should remain constant. Over the long term these numbers are expected to decrease as the newer E and F models replace them.

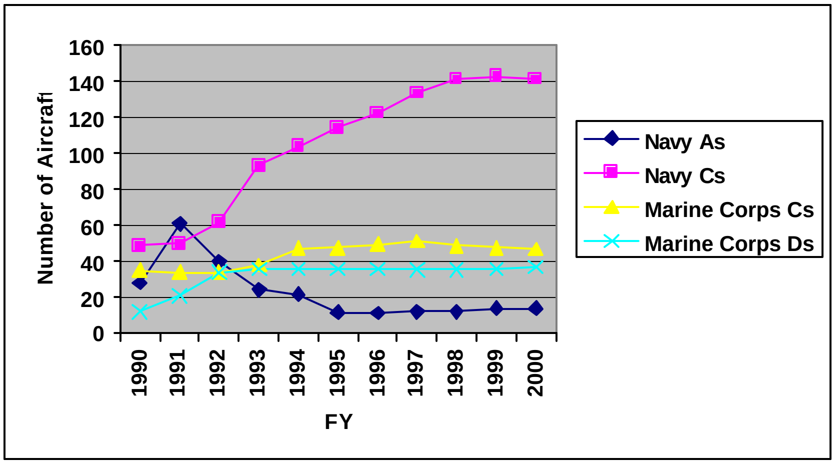

Figure 3-6. Total Number of Airframes Per Model.

The final step in estimating future AVDLR costs is to determine the average number of hours flown per aircraft per year. Figure 3-7 shows how the average number of hours flown per aircraft per year has gradually decreased since Desert Storm/Shield in 1991. Three different regressions were completed to find the best method to estimate future values. The first method was a regression of actual hours per aircraft vs. fiscal years. The second and third regressions were completed in the same manner but used a two and three year moving average vs. fiscal years. The best results came from using the two-year moving average. Table 3-1 shows the regression results of using a two-year moving average. The high R^2 in Table 3-1 indicate that there is a strong correlation between the two-year moving average and the fiscal year. Graphs of each T/M/S two–year moving vs. actual hours per aircraft per year is shown in Appendix G.

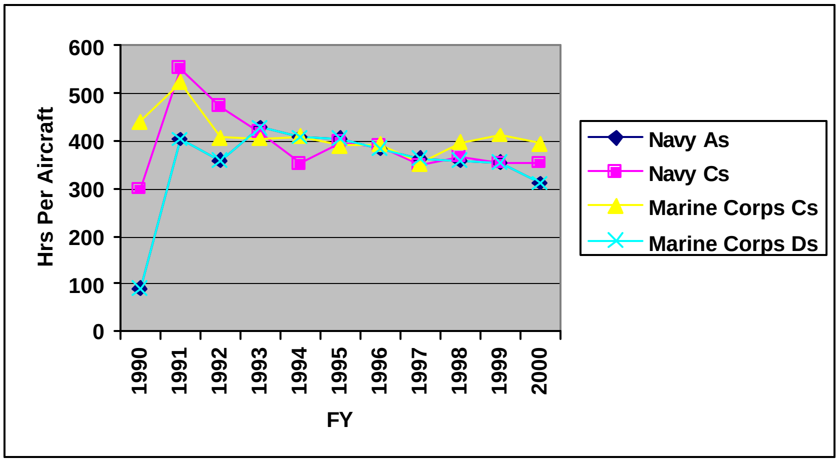

Figure 3-7. Hours Per Aircraft Per Year.

Regression Results		
Model	**R^2**	***t statistic***
Navy As	85.88	-6.975
Navy Cs	63.52	-3.733
Marine Corps Cs	85.88	-6.975
Marine Corps Ds	94.34	-10.004

Table 3-1. Two-Year Moving Average Regression Results.

By using the information from the regression analysis, future expected hours per aircraft per year can be determined and are listed in Appendix F.

Putting the appropriate values for each T/M/S for each year back into Equation 3-1 determines the total AVDLR cost for each T/M/S. The total annual AVDLR cost is the summation of the four different models. The results of this model are depicted in Table 3-2.

Fiscal Year	Navy A's	Navy C's	Marine Corps C's	Marine Corps D's	Total Costs
2001	$11,916,671	$88,001,768	$33,053,251	$22,747,200	**$155,718,890**
2002	$11,958,367	$90,852,858	$34,739,741	$23,325,817	**$160,876,783**
2003	$11,885,087	$93,158,638	$36,308,563	$23,735,784	**$165,088,072**
2004	$11,696,831	$94,919,107	$37,759,715	$23,977,103	**$168,352,756**
2005	$11,393,600	$96,134,266	$39,093,199	$24,049,772	**$170,670,836**
2006	$10,975,393	$96,804,114	$40,309,014	$23,953,791	**$172,042,312**
2007	$10,442,210	$96,928,652	$41,407,160	$23,689,161	**$172,467,183**
2008	$9,794,051	$96,507,880	$42,387,638	$23,255,882	**$171,945,450**
2009	$9,030,917	$95,541,797	$43,250,446	$22,653,953	**$170,477,113**

Table 3-2. Forecasted AVDLR Costs.

The results in Table 3-2 show that total AVDLR costs should continue to increase until Fiscal Year 2007 and then start to decline in the following two years. As AVDLR costs increase, the trend at CNAP has been for total hours flown to decrease. The model predicts that as these costs continue to increase, CNAP will have to decrease the number of hours flown to pay for the rise in AVDLR costs unless additional funding is provided.

D. SUMMARY

In this chapter, CNAP's data were provided and the results of the models estimates were also discussed. The model estimates that CNAP's F/A-18 AVDLR costs should continue to increase until Fiscal Year 2007. After Fiscal Year 2007, the model estimates AVDLR cost should begin to decline since CNAP will have to fly fewer hours to pay for the increasing AVDLR CPH.

The next chapter will provide a comparison and analysis of the model's estimates to the actual values for Fiscal Year 2001. The comparison and analysis will look at the two values and try to explain any significant differences between the two.

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IV. ANALYSIS

A. INTRODUCTION

The purpose of this chapter is to first, test the solutions provided in Chapter III and second, to conduct an analysis as to what caused any differences to occur in the actual and forecasted values. These two steps correspond to steps five and six in the quantitative analysis approach.

B. TEST THE SOLUTIONS

Commander Naval Air Forces Pacific's (CNAP) Fiscal Year's 2001 results were compared to the forecasted results and these results are listed below.

FY 2001	Navy A's	Navy C's	Marine Corps C's	Marine Corps D's
Actual	3616.40	2551.69	1788.27	1950.40
Forecasted	3964.56	1932.50	1932.50	2036.90
% Difference	9.6%	-24.3%	8.1%	4.4%

Table 4-1. Actual vs. Forecasted AVDLR CPH.

Table 4-1 shows the actual Aviation Depot Level Repair (AVDLR) Cost Per Hour (CPH) compared to the model's estimates. From the table, the results show that the model was unsuccessful in estimating 2001 AVDLR costs to within 1% of the actual results for all aircraft models. Navy A models have had a 13.5% average annual increase in AVDLR costs for the past ten years. In Fiscal Year 2001, Navy A models had a 10.7% increase in costs from the previous year. Even though last year's increase was in line with their average annual rate of increase, the model anticipated a much larger increase in costs which is why it failed to meet its objectives.

Navy C model AVDLR costs showed an unexpected increase in cost when compared to estimated values. Navy C models have had a 12% average annual increase in AVDLR costs for the past ten years. For Fiscal Year 2001, annual AVDLR costs rose by more than 27% from the previous year. A 27% increase in costs is such an extreme value that is almost two standard deviations away from the mean, making it almost impossible to predict a value of this size. Commander Naval Air Forces Pacific attributes the rise in costs to their more accurate costing practices. Their new accounting practice makes it possible to track F/A-18 common parts more precisely which may have resulted in the unexpected decrease in Navy A models' costs and the unexpected rise in Navy C models' costs. Since Navy C model AVDLR costs represent nearly 60% of CNAP's TACAIR F/A-18 AVDLR costs, it is thus important to have an accurate estimate of their costs since it can significantly affect the model's overall success.

Marine Corps C models also showed a significant rise in AVDLR costs. Marine Corps C models have had a 17% average annual increase in AVDLR costs for the past ten years. For Fiscal Year 2001, Marine Corps C models had a 5.6% decrease from the previous year. Since the model anticipated an increase in costs, this caused it to be over the actual value.

The model was also unable to estimate Marine Corps D model's AVDLR CPH to with in 1% of the actual value. Marine Corps D models have had a 15% average annual increase in costs for the past ten years. For Fiscal Year 2001, Marine Corps D models had a 1.7% decrease in costs from the previous year. The model was again anticipating an increase in costs leading to an overestimation of its costs.

FY 2001	**Navy A's**	**Navy C's**	**Marine Corps C's**	**Marine Corps D's**
Actual	12.4	141.6	47.0	36.6
Forecasted	12.0	141.0	47.0	36.0
% Difference	-3.2%	-0.4%	0.0%	-1.6%

Table 4-2. Actual vs. Forecasted Numbers of Airframes per Model.

The estimates for the number of aircraft per model were very close to the actual results, which can be seen in Table 4-2. Only Navy As and Marine Corps D models were outside the 1% goal. Fiscal Year 2002 numbers should remain constant, but Fiscal Year 2003 should see decreases in Navy A and C models because the newer E and F models will begin replacing the older aircraft in the tactical squadrons.

FY 2001	Navy A's	Navy C's	Marine Corps C's	Marine Corps D's
Actual	340.24	329.4	383.15	358.82
Forecasted	250.48	325.27	363.91	310.21
% Difference	-26.4%	-1.3%	-5.0%	-13.5%

Table 4-3. Actual vs. Forecasted Average Number of Hrs per Aircraft.

Reviewing Table 4-3 shows the model was unable to meet its goal in forecasting the average number of hours per aircraft to within 1% of the actual amount. Navy A models estimates were 26.4% below the actual values. For the past ten years, Navy A models have had an average annual decrease of 9% in hours flown per aircraft. With an increase of 26.4 %, this value is over two standard deviations away from the mean making it almost impossible to estimate. Even though the model's estimate of Navy A's average number of hours per aircraft per year was so disproportionate, Navy A's only represent 5% of the total number of hours flown for CNAP's F/A-18s.

Navy C's average number of hours per aircraft was very close to the estimated value. On average, Navy C's have had a 5% decrease in the number of hour flown per aircraft per year for the last ten years. The calculation of Navy C's hours per airframe is an important factor to determine since the majority of the AVDLR costs are associated with this service and model airframe.

The model was also unable to meet the objective of estimating Marine Corps C's hours per aircraft to within 1%. Marine Corps C's have had an average annual decrease of 3% in the amount of hours flown per aircraft per year for the last ten years. The model anticipated a greater decrease than what was experienced.

Marine Corps D's had an increase in number of hours flown per aircraft. Marine Corps D's have had an average annual decrease of 3% for the last ten years but for Fiscal Year 2001 there was an increase of 15% in hours flown. The increase in the number of hours flown was an attempt by D squadrons to increase their Primary Mission Readiness rate (PMR) from 74.9% in 2000 to 83% to meet the goal set by the Chief of Naval Operations.

Table 4-4 shows the final AVDLR cost results for each model. The model's estimate was 19.0% below the actual costs. The majority of the increase in costs resulted from Navy C models which represent almost 63% of CNAP's total AVDLR costs. Table 4-5 shows that the OP-20 version 1245, the version used to make the Fiscal Year 2001 budget estimates, was also off by 17.7 % with the majority of the difference resulting from Navy C models AVDLR costs.

FY 2001	Navy A's	Navy C's	Marine Corps C's	Marine Corps D's	Total
Actual	15,257,000	119,061,000	32,203,000	25,614,000	192,135,000
Forecasted	11,916,671	88,001,768	33,053,251	22,747,200	155,718,890
% Difference	-21.9%	-26.1%	2.6%	-11.2%	**-19.0%**

Table 4-4. Actual vs. Forecasted AVDLR Total Costs.

FY 2001	Navy A's	Navy C's	Marine Corps C's	Marine Corps D's	Total
Actual	15,257,000	119,061,000	32,203,000	25,614,000	192,135,000
OP-20 v1245	14,972,000	89,171,000	31,435,000	22,569,000	158,147,000
% Difference	-1.9%	-25.1%	-2.4%	-11.9%	**-17.7%**

Table 4-5. Actual vs. OP-20v1245.

C. CAUSES FOR INCREASES IN AVDLR COSTS

There are many reasons why F/A-18 AVDLR costs have increased over the past ten years. One of the primary objectives of this research was to determine if there was any relationship between the age of the airframe and the rise in AVDLR costs. A second objective was to see if the F/A-18 utilization rate also contributes to the rise in AVDLR costs.

Two studies completed by the Center for Naval Analyses (CNA) show that the age of the aircraft contributes to the rise in AVDLR costs. According to a 1991 Center for Naval Analyses (CNA) study [Ref. 18], depot level repairs should increase by 1-3 percent per year of age increase of the aircraft after adjusting for inflation. If new aircraft are continually purchased to replace older aircraft then the average age does not increase and, according to the study, depot costs should not increase.

Determining how accurate this estimate is required making some assumptions on the age of CNAP's F/A-18s. Using the data provided in Chapter III, Navy A's average 14 years old, Navy and Marine Corps C models average 9.5 years old, and Marine Corps D models average 8.5 years old. To test the 1991 CNA study, it was assumed that the average age of each model decreased by one year from 2000 until 1996. Thus, in 1996 the average age of an A model would be 10 years old and a C and D model would be 5.5 and 4.5 years old respectively. The comparison used 1996 as the starting point for this comparison in order to have five years of data points and because CNAP received only a few aircraft from 1996 to 2000. Therefore, the actual average age of each model should not have been that different from the assumed value.

Next, AVDLR costs for each model were deflated using 2001 constant dollars. The results of this comparison can be seen in Figures 4-1 through 4-3. In Figure 4-1, Navy A's AVDLR CPH are high when compared to the CNA's 1991 estimates. Although Navy A models have had an average annual increase of 13.5 % for the past ten years for the period covered in this comparison (1996-2000), they averaged a 5.19% annual increase in costs. Consequently, even though Navy A's AVDLR CPH are much higher than for any other model if the age difference is factored out, the CPH increases are low when compared to the other models. They are still high when compared to the 1991 CNA estimates.

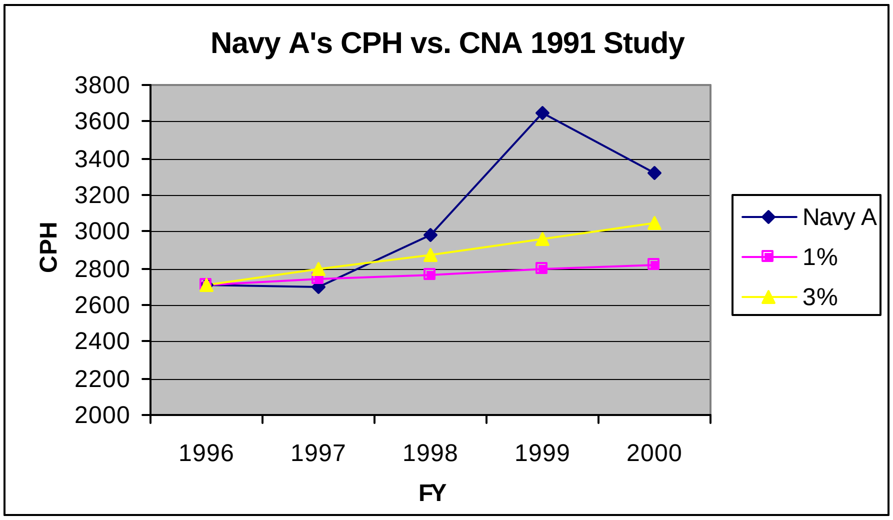

Figure 4-1. Navy A's CPH vs. 1991 CNA Study.

Figure 4-2 shows that the 1991 CNA was off in its estimates of Navy and Marine Corps C model AVDLR costs. There was an average annual increase in AVDLR costs of 12% and 17% for Navy and Marine Corps C models. For the period covered in the comparison, (1996-2000), Navy C models demonstrated an average annual increase of 13.45% and Marine Corps C models a 11.26% increase in costs.

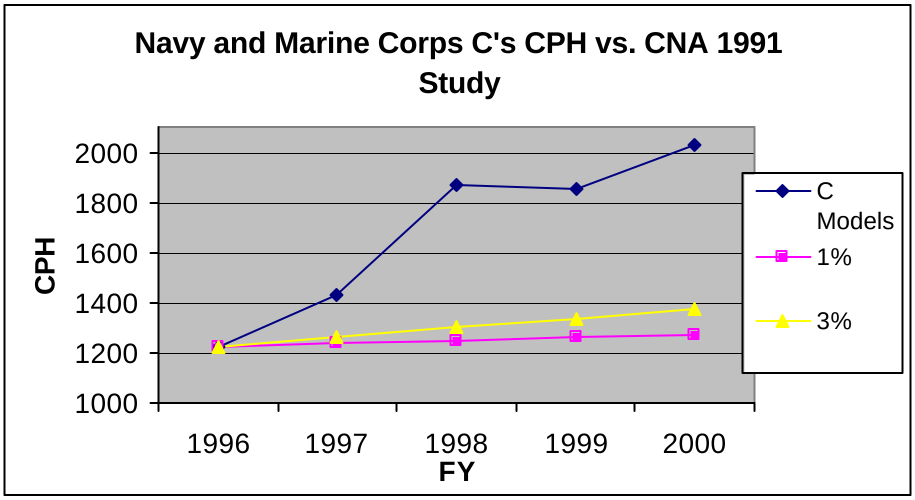

Figure 4-2. Navy and Marine Corps C's CPH vs. 1991 CNA Study.

Finally, Figure 4-3 shows that Marine Corps D's have high AVDLR CPH that exceeds the 1991 CNA study's estimates. Marine Corps D models demonstrated a ten-year average annual increase in costs of 15%. For the period covered in the comparison Marine Corps D models had a 15.97% average annual increase in cost.

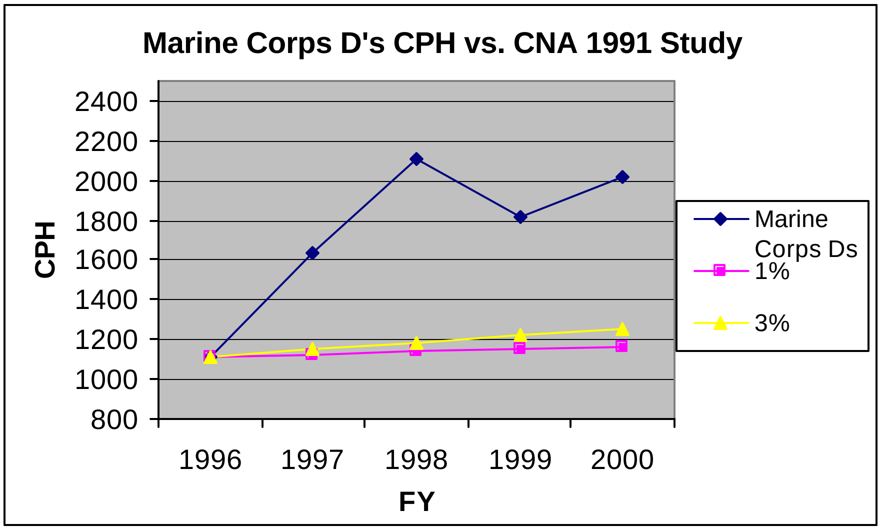

Figure 4-3. Marine Corps D's CPH vs. 1991 CNA Study.

The Center for Naval Analyses completed a second study in 2001 [Ref. 19] that suggests tactical aircraft should have an exponential growth rate of about 8% in depot level component repairs costs per flight hour per year of increase in age of the airframe. Using the same assumptions as in the 1991 study, a comparison of actual costs to the 2001 CNA study was completed. Figure 4-4 shows that Navy A models are slightly below the study's estimates. However, by referring to Figures 4-5 through 4-7, it can be seen that Navy and Marine Corps C and D models have a much higher AVDLR CPH than the estimates of the 2001 CNA study.

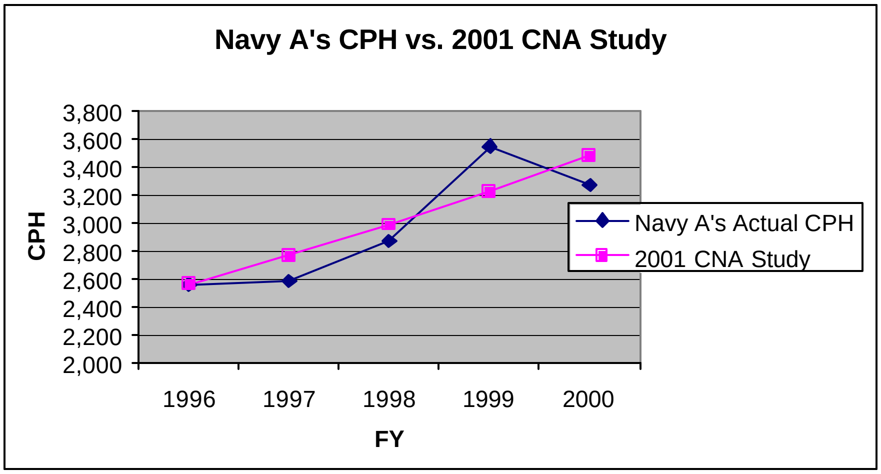

Figure 4-4. Navy A's CPH vs. 2001 CNA Study.

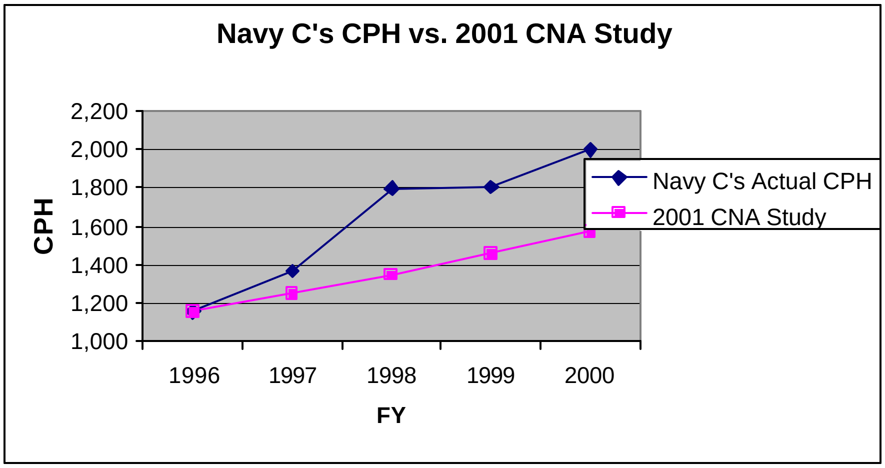

Figure 4-5. Navy C's CPH vs. 2001 CNA Study.

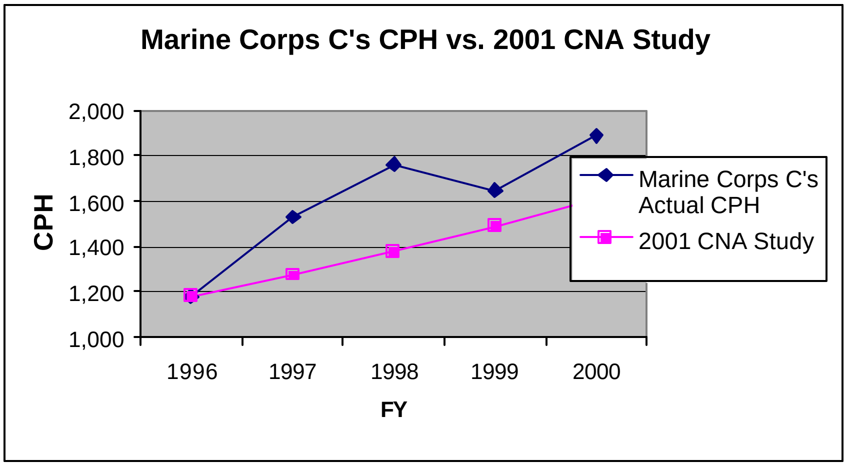

Figure 4-6. Marine Corps C's CPH vs. 2001 CNA Study.

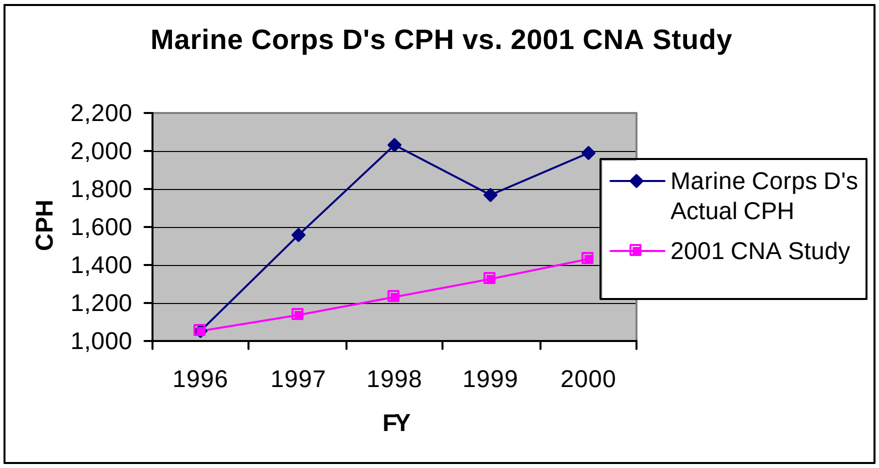

Figure 4-7. Marine Corps D's CPH vs. 2001 CNA Study.

The conclusion to be drawn from both studies is that the age of the aircraft does affect the cost of depot level repairs. For CNAP's F/A-18's, the rise in AVDLR costs could range from a 5% increase to as high as a 15% increase when adjusted for inflation or from 6.5% to 17.23% when not adjusted for inflation. In either case, if CNAP does not receive any new aircraft, their AVDLR costs can be expected to double in four to eleven years.

The utilization rate has also affected the increase in AVDLR costs for CNAP's F/A-18s. Using data from the CNAP's Aviation Cost Evaluation System (ACES), since 1995, CNAP's total TACAIR utilization rate has averaged 30 hours per aircraft per month. Using a weighted average for CNAP's F/A-18's, their utilization rate has been 31.8 hours per aircraft per month. This means that CNAP is flying its F/A-18's at a 6% higher utilization rate per month than its TACAIR average. Unfortunately, for the same period, CNAP's average level of funding has only supported 30.5 hours per month rate, which is a 4.3% average annual funding shortfall. Flying more hours than the amount budgeted creates many problems for CNAP and its F/A-18s. Flying aircraft more than expected causes more parts to be replaced and forces the aircraft into the depot sooner than anticipated. This, in turn, causes AVDLR costs to rise.

The F/A-18's F-404 engines are one component that has been subjected to the effects of both increased age and operating under a high utilization rate. For CNAP's F/A-18's, this has been a significant contributor to the increase in AVDLR costs [Ref. 13]. Three engine components that contributed to this increase in costs are the High Pressure Turbine (HPT), the Fan Rotor Assembly and the Low Pressure Turbine (LPT). Their significant life cycle reductions have in part contributed to the rise in AVDLR costs. Table 4-6 shows that some of the HPT components showed up to a 31.4% reduction in life while the Fan Section and LPT demonstrated up to 62.3% and 45.8% life cycle reductions.

		Original	**As of 1/94**	**% Life Lost**
I.	**FAN SECTION**			
	Stage 1	5850	2200	**62.30%**
	Stage 2	8770	3100	**64.60%**
	Stage 3	4380	1700	**61.10%**
	Aft Shaft	9030	4600	**49.00%**
II.	**LOW PRESSURE TURBINE**			
	Disc	10520	6240	**40.60%**
	Fwd Air Seal	22030	18000	**18.20%**
	Conical Shaft	12370	5700	**45.80%**
III.	**HGH PRESSURE TURBINE**			
	Disc	10500	7200	**31.40%**
	Fwd Cooling Plate	2100	1600	**23.80%**

Table 4-6. F-404 Engine Component Life Reductions [From: Ref. 7].

When the life cycle reductions of some of the engines major rotating components are combined with the increased cost of parts, it can be seen that the problems the F/A-18 is experiencing today is a higher than normal annual increase in AVDLR expenses.

D. SUMMARY

In this chapter, the actual results were compared to the estimated values and any differences between the two values were explained. The chapter also looked at how age and high utilization rate affects the F/A-18 AVDLR costs. Finally, the chapter discussed which components were the largest contributors to the increase in AVDLR costs for CNAP.

V. CONCLUSION

The goal of this thesis was to develop a model that Commander Naval Air Forces Pacific (CNAP) could use to estimate future Aviation Depot Level Repair (AVDLR) costs for their TACAIR F/A-18s. Accomplishing this required completing three major tasks. The first was to develop an approach to solve this problem. Second, to determine which model would achieve the best results, and the last step was to analyze the actual results when compared to the model's outcomes.

The first component of this research was to develop an approach to solve this problem. The quantitative method was selected because it provided a simple and flexible method to develop a solution to this problem.

The second component was to determine which model would be used that could achieve the best results. From the literary review, several theses used regression analysis as the sole method to determine future AVDLR costs. Their regression analysis involved comparing AVDLR costs to the number of hours flown. The results from this review were mixed. One thesis obtained a strong correlation between the two variables while the other had no correlation between the two variables. This thesis tried a different approach of using a time-series analysis to estimate future AVDLR costs.

The third component of this research was to analyze the actual results when compared to model's outcomes. After the completion of the analysis, corrections can be made to the model to make it more accurate in future year estimates.

A. SUMMARY OF RESEARCH QUESTIONS

The three research questions listed in Chapter I were answered.

- Is there any evidence to show that CNAP has spent more money on AVDLR costs to maintain its older model F/A-18s?

This question was answered in Chapter IV. There is strong evidence that shows CNAP has spent more money on AVDLR costs to maintain its older model F/A-18s. Navy A models, on average, are older than any other models and also have the highest AVDLR costs. The results in Chapter IV also show that for a one-year increase in a model's average age, CNAP can expect to pay an additional 5%-15% in AVDLR costs.

- How close are budgeted costs to actual costs and if there is a discrepancy, what caused it?

This question was answered in Chapter IV. Commander Naval Air Forces Pacific's budgets have been, on average, 4.3 % below the actual costs for the past ten years. There are several reasons why this has occurred but one of the most significant is the increase in AVDLR costs. The average annual increase in AVDLR costs has far exceeded any annual increase in CNAP's Flying Hour Programs (FHP) budget. As a result, CNAP's FHP has been under-funded, causing them to use money from other programs to pay for the unexpected increase in the F/A-18s FHP's budget.

- Are there any components that have had a shorter life cycle than what was expected, and if so, did they contribute to the rising costs at CNAP?

This question was answered in Chapter IV. Major components on the F404 engine have had shorter life cycles than expected. The High Pressure Turbine (HPT), Fan Rotor Assembly and the Low Pressure Turbine (LPT) are some components which have had a significant decrease in the expected life cycle time. These components also contributed to the rise in AVDLR costs for CNAP. Since components need to be replaced earlier than expected, more maintenance costs are incurred causing AVDLR costs to increase.

B. RECOMMENDATIONS FOR FURTHER STUDY

One area for future research is to see whether the new E and F models, which are to replace the older A and C models, actually lower CNAP's F/A-18 AVDLR costs. Research completed by the Center for Naval Analyses states that as the Navy replaces its older aircraft, it should experience lower AVDLR costs. Research into this topic could indicate if this holds true for CNAP's F/A-18s.

A second area for future research is looking at how the changes in the cost recovery rates affect the changes in AVDLR expenses at CNAP.

C. CONCLUSION

There are many variables that cause AVDLR costs to increase. These variables can range from changes to the cost recovery rates caused from labor union strikes to a decrease in a component's expected life cycle time. Since there are so many variables that can affect changes in AVDLR costs, it is almost impossible for an AVDLR costs model to consistently estimate AVDLR costs to within 1% of the actual yearly costs. To help solve for this problem, a model should only estimate AVDLR costs on a quarterly basis instead of yearly. If the model can do this, it may be more accurate because of the shorter time variables affecting AVDLR costs.

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APPENDIX A. SUMMARY OF FLIGHT HOUR COSTS

Navy F/A-18As

Fiscal Year	Total Force	Total Hours	Hours/Aircraft	Fuel Costs/Hr	AVDLR Costs/Hr	AFM Costs/Hr
1990	28.00	14,655.00	523.39	662.02	899.10	574.29
1991	61.00	18,966.00	310.92	1,061.71	867.18	584.97
1992	40.10	17,202.00	428.98	731.32	705.81	413.58
1993	24.30	9,315.00	383.33	646.50	1,532.02	749.37
1994	21.50	8,183.00	380.60	931.35	1,557.66	298.11
1995	11.50	3,338.00	290.26	717.38	3,923.88	1,237.08
1996	11.25	3,817.00	339.29	855.97	2,558.32	815.12
1997	12.00	3,550.00	295.83	850.05	2,582.36	1,007.92
1998	12.00	4,118.00	343.17	1,058.16	2,871.77	1,143.13
1999	13.83	3,636.00	262.91	965.75	3,545.29	1,185.23
2000	14.08	3,076.00	218.47	771.90	3,268.58	1,313.47

Navy F/A-18Cs

Fiscal Year	Total Force	Total Hours	Hours/Aircraft	Fuel Costs/Hr	AVDLR Costs/Hr	AFM Costs/Hr
1990	49.00	14,663.00	299.24	620.93	706.04	508.11
1991	50.00	27,646.00	552.92	1,080.89	915.34	438.72
1992	62.00	29,310.00	472.74	726.77	715.06	507.46
1993	93.20	39,058.00	419.08	755.61	967.02	406.65
1994	104.00	36,661.00	352.51	883.40	1,306.14	463.27
1995	114.60	45,460.00	396.68	761.38	1,506.40	587.01
1996	122.83	47,847.00	389.54	824.99	1,155.61	543.94
1997	133.80	46,650.00	348.65	875.74	1,368.02	664.96
1998	141.67	52,079.00	367.61	1,005.98	1,799.59	724.15
1999	143.33	50,731.00	353.95	952.80	1,803.85	889.07
2000	141.67	50,177.00	354.18	712.76	1,998.03	942.99

Marine Corps F/A-18Cs

Fiscal Year	Total Force	Total Hours	Hours/Aircraft	Fuel Costs/Hr	AVDLR Costs/Hr	AFM Costs/Hr
1990	35.00	15,430.00	440.86	656.01	408.47	239.76
1991	34.00	17,793.00	523.32	1,093.55	758.94	419.21
1992	33.90	13,818.00	407.61	758.33	663.88	447.75
1993	38.20	15,440.00	404.19	767.09	788.96	496.01
1994	47.20	19,325.00	409.43	861.16	1,176.14	532.82
1995	48.00	18,722.00	390.04	774.07	1,294.14	628.44
1996	49.58	19,489.00	393.08	758.75	1,180.92	610.75
1997	51.30	18,091.00	352.65	829.17	1,532.22	447.99
1998	48.75	19,345.00	396.82	916.69	1,761.24	875.51
1999	47.50	19,580.00	412.21	802.34	1,648.34	1,138.66
2000	47.00	18,520.00	394.04	691.10	1,888.56	784.57

Marine Corps F/A-18Ds

Fiscal Year	Total Force	Total Hours	Hours/Aircraft	Fuel Costs/Hr	AVDLR Costs/Hr	AFM Costs/Hr
1990	12.00	1,079.00	89.92	621.62	492.32	390.19
1991	21.00	8,504.00	404.95	1,016.79	765.41	424.03
1992	33.80	12,161.00	359.79	723.75	728.03	406.58
1993	36.00	15,428.00	428.56	768.47	962.00	474.47
1994	36.00	14,729.00	409.14	828.54	1,065.00	403.74
1995	36.00	14,622.00	406.17	745.65	1,340.52	717.25
1996	36.00	13,839.00	384.42	803.74	1,052.09	585.69
1997	35.50	12,891.00	363.13	833.69	1,560.24	749.84
1998	35.58	12,784.00	359.30	937.49	2,035.15	931.00
1999	36.00	12,790.00	355.28	869.63	1,766.58	1,014.22
2000	36.83	11,467.00	311.35	605.19	1,985.65	908.17

APPENDIX B. TIME SERIES ANALYSIS FOR NAVY F/A-18AS

Spreadsheet Model for Classical Decomposition Method

Year	Year	Y	Mov. Avg.	Y/MA	S	Y/S	Y=T*S
1990	1	899.10			1.029	873.8	730.17
1991	2	867.18	824.0	1.052	0.895	968.9	940.23
1992	3	705.81	1035.0	0.682	1.081	652.7	1486.05
1993	4	1,532.02	1265.2	1.211	1.029	1488.8	1747.26
1994	5	1,557.66	2337.9	0.666	0.895	1740.4	1809.48
1995	6	3,923.88	2680.0	1.464	1.081	3628.7	2536.27
1996	7	2,558.32	3021.5	0.847	1.029	2486.2	2746.66
1997	8	2,582.36	2670.8	0.967	0.895	2885.3	2678.73
1998	9	2,871.77	2999.8	0.957	1.081	2655.8	3586.49
1999	10	3,545.29	3228.5	1.098	1.029	3445.4	3746.05
2000	11	3,268.58			0.895	3652.0	3547.98
2001	12				1.081		4636.72
2002	13				1.029		4745.44
2003	14				0.895		4417.23
2004	15				1.081		5686.94
2005	16				1.029		5744.84
2006	17				0.895		5286.48
2007	18				1.081		6737.16
2008	19				1.029		6744.23
2009	20				0.895		6155.73
2010	21				1.081		7787.38

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.887318
R Square	0.787334
Adjusted R Square	0.763704
Standard Error	550.7889
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	10108176	10108176	33.31981	0.000269
Residual	9	2730315	303368.4		
Total	10	12838491			

	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	406.4563	356.1785	1.141159	0.283258	-399.276	1212.189	-399.276	1212.189
X Variable 1	303.1378	52.51566	5.772331	0.000269	184.339	421.9365	184.339	421.9365

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APPENDIX C. TIME SERIES ANALYSIS FOR NAVY F/A-18CS

Spreadsheet Model for Classical Decomposition Method

Year	Year	Y	Mov. Avg.	Y/MA	S	Y/S	Y=T*S
1990	1	706.04			1.0615	665.1	659.19
1991	2	915.34	778.8	1.175	1.0933	837.2	830.96
1992	3	715.06	865.8	0.826	0.8430	848.2	757.90
1993	4	967.02	996.1	0.971	0.9600	1007.3	996.55
1994	5	1,306.14	1259.9	1.037	1.0615	1230.5	1249.49
1995	6	1,506.40	1322.7	1.139	1.0933	1377.8	1438.96
1996	7	1,155.61	1343.3	0.860	0.8430	1370.8	1226.69
1997	8	1,368.02	1441.1	0.949	0.9600	1425.0	1530.40
1998	9	1,799.59	1657.2	1.086	1.0615	1695.3	1839.79
1999	10	1,803.85	1867.2	0.966	1.0933	1649.9	2046.96
2000	11	1,998.03			0.8430	2370.1	1695.48
2001	12				0.9600		2064.26
2002	13				1.0615		2430.09
2003	14				1.0933		2654.96
2004	15				0.8430		2164.27
2005	16				0.9600		2598.12
2006	17				1.0615		3020.39
2007	18				1.0933		3262.97
2008	19				0.8430		2633.07
2009	20				0.9600		3131.97
2010	21				1.0615		3610.69

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.949234
R Square	0.901045
Adjusted R Square	0.89005
Standard Error	161.0697
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2126075.2	2126075	81.95036	8.14E-06
Residual	9	233491.05	25943.45		
Total	10	2359566.2			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	481.9713	104.15891	4.627269	0.001241	246.3473	717.5953	246.34727	717.5953
X Variable 1	139.025	15.357394	9.052644	8.14E-06	104.2842	173.7659	104.28415	173.7659

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APPENDIX D. TIME SERIES ANALYSIS FOR MARINE CORPS F/A-18CS

Spreadsheet Model for Classical Decomposition Method

Year	Year	Y	Mov. Avg.	Y/MA	S	Y/S	Y=T*S
1990	1	408.47			1.076	379.6	480.78
1991	2	758.94	610.4	1.243	1.080	702.9	643.73
1992	3	663.88	737.3	0.900	0.892	744.3	665.11
1993	4	788.96	876.3	0.900	0.964	818.8	862.37
1994	5	1,176.14	1086.4	1.083	1.076	1093.1	1123.82
1995	6	1,294.14	1217.1	1.063	1.080	1198.6	1288.96
1996	7	1,180.92	1335.8	0.884	0.892	1323.9	1198.18
1997	8	1,532.22	1491.5	1.027	0.964	1590.3	1438.17
1998	9	1,761.24	1647.3	1.069	1.076	1636.8	1766.86
1999	10	1,648.34	1766.0	0.933	1.080	1526.7	1934.19
2000	11	1,888.56			0.892	2117.2	1731.26
2001	12				0.964		2013.98
2002	13				1.076		2409.90
2003	14				1.080		2579.41
2004	15				0.892		2264.33
2005	16				0.964		2589.79
2006	17				1.076		3052.93
2007	18				1.080		3224.64
2008	19				0.892		2797.41
2009	20				0.964		3165.59
2010	21				1.076		3695.97

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.973552
R Square	0.947804
Adjusted R Square	0.942004
Standard Error	122.5745
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2455390	2455390	163.4257	4.48E-07
Residual	9	135220.6	15024.51		
Total	10	2590610			

	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	297.4197	79.26522	3.75221	0.004539	118.1092	476.7302	118.1092	476.7302
X Variable 1	149.4046	11.68702	12.7838	4.48E-07	122.9667	175.8425	122.9667	175.8425

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APPENDIX E. TIME SERIES ANALYSIS FOR MARINE CORPS F/A-18DS

Spreadsheet Model for Classical Decomposition Method

Year	Year	Y	Mov. Avg.	Y/MA	S	Y/S	Y=T*S
1990	1	492.32			1.0440	471.6	480.54
1991	2	765.41	661.9	1.156	1.078	709.8	670.60
1992	3	728.03	818.5	0.889	0.844	863.1	660.88
1993	4	962.00	918.3	1.048	1.028	936.3	971.09
1994	5	1,065.00	1122.5	0.949	1.044	1020.1	1155.40
1995	6	1,340.52	1152.5	1.163	1.078	1243.1	1367.67
1996	7	1,052.09	1317.6	0.798	0.844	1247.3	1206.14
1997	8	1,560.24	1549.2	1.007	1.028	1518.5	1635.29
1998	9	2,035.15	1787.3	1.139	1.044	1949.4	1830.27
1999	10	1,766.58	1929.1	0.916	1.078	1638.3	2064.73
2000	11	1,985.65			0.844	2354.1	1751.40
2001	12				1.028		2299.49
2002	13				1.044		2505.14
2003	14				1.078		2761.79
2004	15				0.844		2296.65
2005	16				1.028		2963.69
2006	17				1.044		3180.00
2007	18				1.078		3458.85
2008	19				0.844		2841.91
2009	20				1.028		3627.89
2010	21				1.044		3854.87

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.958649
R Square	0.919009
Adjusted R Square	0.91001
Standard Error	167.7227
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2872816	2872816	102.1232	3.278E-06
Residual	9	253178	28130.89		
Total	10	3125994			

	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	298.6779	108.4612	2.753777	0.022338	53.321474	544.0343	53.32147	544.0343
X Variable 1	161.606	15.99173	10.1056	3.28E-06	125.4302	197.7819	125.4302	197.7819

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APPENDIX F. MODELS EXPECTED VALUES

Fiscal Year	Navy A's	Navy C's	Marine Corps C's	Marine Corps D's
2001	3964.56	1932.50	1932.50	2036.90
2002	4256.91	2079.70	2079.70	2194.10
2003	4549.27	2226.91	2226.91	2351.31
2004	4841.62	2374.11	2374.11	2508.51
2005	5133.98	2521.31	2521.31	2665.71
2006	5426.33	2668.51	2668.51	2822.91
2007	5718.69	2815.71	2815.71	2980.11
2008	6011.04	2962.91	2962.91	3137.31
2009	6303.40	3110.12	3110.12	3294.52

AVDLR COSTS PER HOUR

Fiscal Year	Navy A's	Navy C's	Marine Corps C's	Marine Corps D's
2001	250.48	325.27	363.91	310.21
2002	234.10	312.04	355.41	295.31
2003	217.71	298.81	346.90	280.41
2004	201.32	285.58	338.40	265.51
2005	184.94	272.35	329.90	250.61
2006	168.55	259.12	321.39	235.71
2007	152.17	245.89	312.89	220.81
2008	135.78	232.66	304.38	205.91
2009	119.39	219.43	295.88	191.01

AVERAGE NUMBER OF HOURS PER AIRCRAFT PER YEAR

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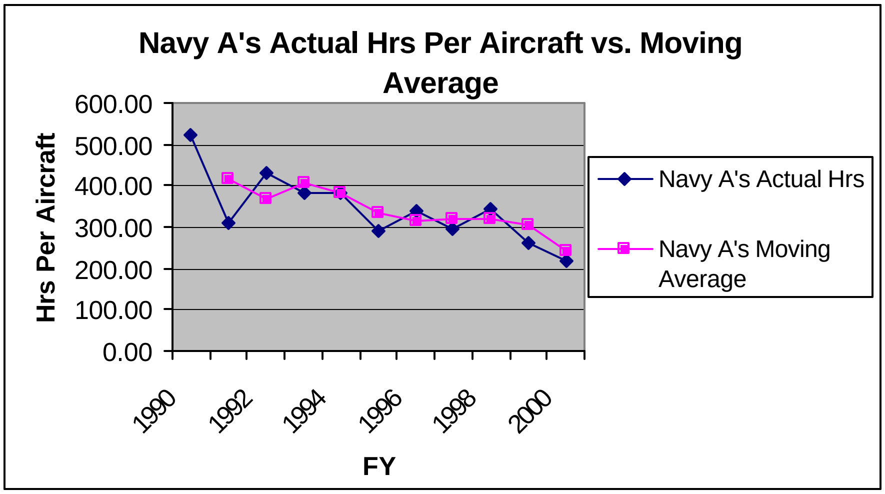
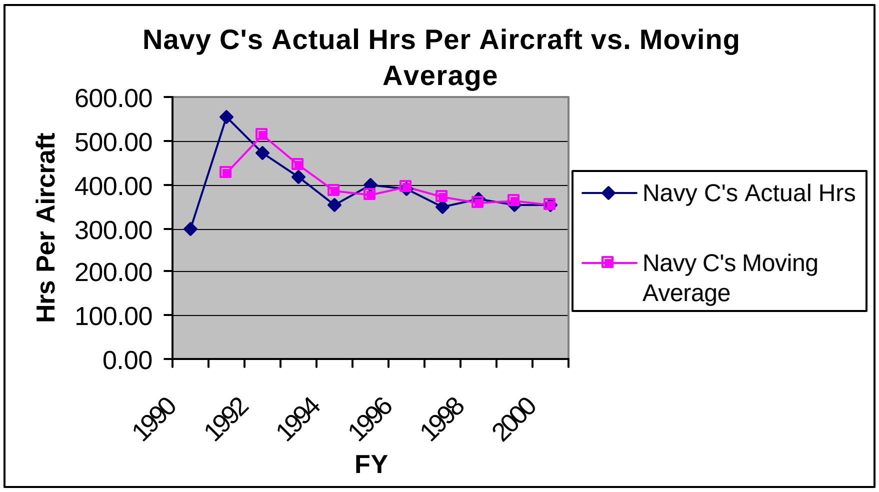
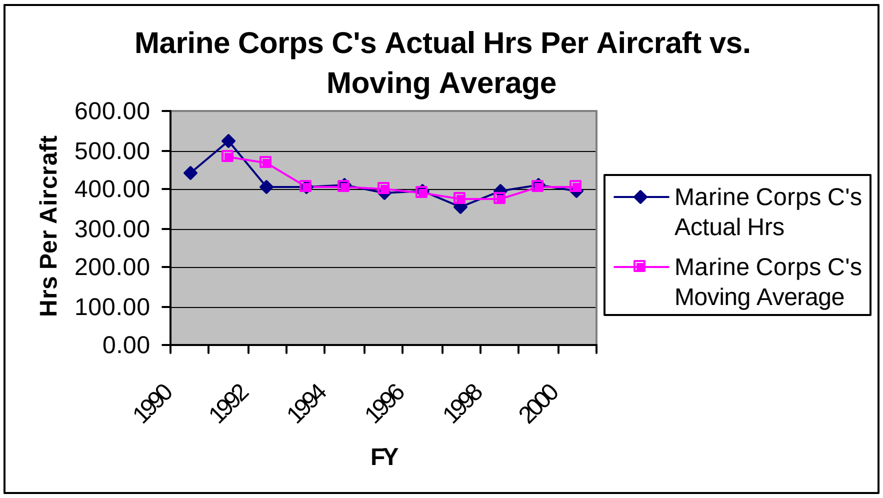
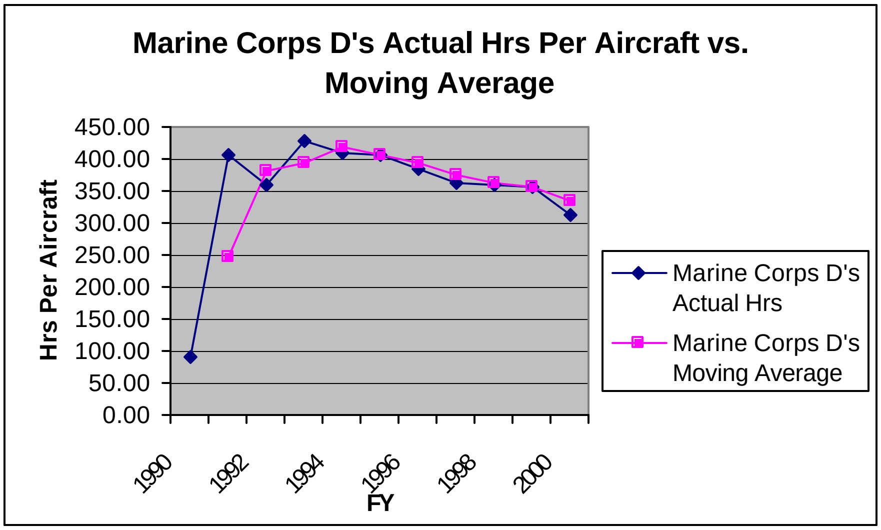
APPENDIX G. ACTUAL HOURS PER AIRCRAFT PER YEAR VS. MOVING AVERAGE






Marine Corps C's Actual Hrs Per Aircraft vs. Moving Average
Hrs Per Aircraft
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1990
1992
1994
1996
1998
2000
FY
Marine Corps C's Actual Hrs
Marine Corps C's Moving Average


Marine Corps D's Actual Hrs Per Aircraft vs. Moving Average
Hrs Per Aircraft
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
1990
1992
1994
1996
1998
2000
FY
Marine Corps D's Actual Hrs
Marine Corps D's Moving Average

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